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Jason Shinazy

(Typed or printed name of person mailing paper or fee)

Jason Shinazy

(Signature of person mailing paper or fee)

Patent
Attorney's Docket No. 023890-031 (SD-8267)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

UTILITY PATENT
APPLICATION TRANSMITTAL LETTER

Box PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Enclosed for filing is the utility patent application of Terry A. Johnson, William C. Replogle and Luis J. Bernardez for IN-VACUUM EXPOSURE SHUTTER.

Also enclosed are:

[X] 2 sheet(s) of [ ] formal [X] informal drawing(s);

[ ] a claim for foreign priority under 35 U.S.C. §§ 119 and/or 365 is [ ] hereby made to _ filed in _ on _;
[ ] in the declaration;

[ ] a certified copy of the priority document;

[ ] a General Authorization for Petitions for Extensions of Time and Payment of Fees;

[ ] _____ statement(s) claiming small entity status;

[ ] an Assignment document;

[X] an Information Disclosure Statement; and

[ ] Other: _____.

[X] An [X] executed [ ] unexecuted declaration of the inventor(s)
[X] also is enclosed [ ] will follow.

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(05/00)

[ ] Please amend the specification by inserting before the first line the sentence --This application claims priority under 35 U.S.C. §§119 and/or 365 to _ filed in _ on _; the entire content of which is hereby incorporated by reference.--

[ ] A bibliographic data entry sheet is enclosed.

[X] The filing fee has been calculated as follows [ ] and in accordance with the enclosed preliminary amendment:

CLAIMS					
	NO. OF CLAIMS		**EXTRA CLAIMS**	**RATE**	**FEE**
Basic Application Fee					$690.00 (101)
Total Claims	26	MINUS 20 =	6	x $18.00 (103)	108.00
Independent Claims	2	MINUS 3 =		x $78.00 (102)	
If multiple dependent claims are presented, add $260.00 (104)					
Total Application Fee					798.00
If verified Statement claiming small entity status is enclosed, subtract 50% of Total Application Fee					
Add Assignment Recording Fee $40.00 (581) if Assignment document is enclosed					
TOTAL APPLICATION FEE DUE					798.00

[ ] This application is being filed without a filing fee. Issuance of a Notice to File Missing Parts of Application is respectfully requested.

[X] A check in the amount of $ 798.00 is enclosed for the fee due.

[ ] Charge $ _____ to Deposit Account No. 02-4800 for the fee due.

[X] The Commissioner is hereby authorized to charge any appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800. This paper is submitted in duplicate.

Please address all correspondence concerning the present application to:

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Respectfully submitted,

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Date: July 5, 2000

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Jason Shinazy
(Typed or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee)

PATENT
Attorney Docket No. 023890-031

IN-VACUUM EXPOSURE SHUTTER

This invention was made with Government support under Contract No. DE-AC04-94AL85000 awarded by the U.S. Department of Energy to Sandia Corporation. The Government has certain rights to the invention.

FIELD OF THE INVENTION

This invention relates to a shutter device, and more particularly, to a vacuum compatible fast shutter device that is suited for controlling a beam of radiation in photolithographic equipment used in the manufacture of integrated circuits.

BACKGROUND OF THE INVENTION

In general lithography refers to processes for pattern transfer between various media. Projection lithography is a powerful and essential tool for microelectronics processing. Figure 4 schematically depicts an apparatus for EUV lithography that comprises a radiation source 21, such as a synchrotron or a laser plasma source, that emits x-rays 22 into condenser 13 which in turn emits beam of light 14 that illuminates a portion of reticle or mask 15. The emerging patterned beam is introduced into the imaging optics 16 which projects an image of mask 15, shown mounted on mask stage 17, onto wafer 18 which is mounted on stage 19. Element 20, an x-y scanner, scans mask 15 and wafer 18 in such

direction and at such relative speed as to accommodate the desired mask-to-image reduction. It may be necessary to shutter the radiation at various positions along the optical path(s) of the radiation. Mechanisms must be in place in the projection lithography system to accomplished this precisely and quickly for a light beam with a large footprint.

SUMMARY OF THE INVENTION

The present invention is directed to an in-vacuum exposure shutter that is capable of shuttering a large footprint light beam in a short time in a vacuum environment. The in-vacuum exposure shutter can be employed in any process or product that requires precise temporal control over a large footprint light beam.

In one aspect, the invention is directed to an exposure device that includes:

a source of radiation that generates an energy beam;

a shutter that includes (i) a frame defining an aperture toward which the energy beam is directed and (ii) a plurality of blades that are secured to the frame; and

means for rotating the shutter to cause the plurality of blades to intercept or allow the energy beam to travel through the aperture.

In one embodiment, each blade has a substantially planar surface and the plurality of blades are secured to the frame such that the planar surfaces of the plurality of blades are substantially parallel to each other. The exposure device is particularly suited for operation in a vacuum environment and can achieve shuttering time from about 0.1 second to 0.001 second or shorter.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an embodiment of the exposure shutter of the present invention;

Figure 2 illustrates the shutter frame;

Figures 3A and 3B illustrate operation of the shutter blades; and

Figure 4 illustrates a photolithography system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates an embodiment of the exposure shutter which includes a support stand 7 onto which is secured solenoid 2 by solenoid cover 3 and solenoid bracket 6. The output shaft 2A of solenoid 2 is connected to shutter frame 8 by a solenoid mount 5, rotary feedthrough 4, and shaft coupling 9. For non-vacuum operations, any suitable rotating device can be employed, for vacuum operations an electrically driven motor or solenoid is preferred. The rotary feedthrough is also preferably employed for vacuum operations. A preferred rotary feedthrough is a ferrofluidic feedthrough which comprises a ferrofluidic seal which provides a hermetic seal against gas and other contaminants in vacuum conditions where a rotary shaft has to be sealed. Ferrofluidic feedthroughs are commercially available from Ferrofluidics Co. Nashua, N.H. For vacuum operations, the solenoid is preferably encased in housing 1 that is essentially impermeable to gas. The housing entraps contaminants that may be discharged from the solenoid.

The shutter frame 8 supports a plurality of shutter blades (not shown) which can intercept radiation (e.g., energy beam) as the frame rotates about center axis x where the frame is attached to the shaft coupling 9 which functions as a pivot. By "energy beam" is meant any flux of electromagnetic radiation (coherent or incoherent) of any frequency including visible light. The shutter frame or wheel includes two circular ring-like members 10,11 that are rigidly held together by a plurality of posts 12 onto which shutter blades are attached. The shutter frame is preferably made of any lightweight metal such as aluminum.

Figure 2 illustrates a partial cross-sectional view of the shutter frame 8 showing the plurality of posts 12 supporting shutter blades 26. The shutter frame should be sufficiently stiff to ensure that there would be little deformation due to the force of the tension created by the shutter blades. One method of attaching a shutter blade is to pass aluminum strips through the rectangular slots 24 in the side between the posts 12 and then winding the strips tightly around the posts. Epoxy is then applied to the flats created by the slots. Thereafter, the strip is held with the weight of the frame providing the force that maintains the strip substantially planar as the epoxy cures. Once the epoxy has cured, excess strip is trimmed off and the process is repeated until all the shutter blades are fabricated. The shutter blades should be parallel to each other so that there is minimum attenuation of the radiation when the shutter device is in the open position.

The shutter blades are made of thin strips of any suitable material that is non-transparent to the radiation of interest. For example, the blades can be made of metal such as aluminum, steel, nickel, or titanium or plastic such as vinyl, polytetrafluoroethylene (e.g., TEFLON), polyimide (e.g., KAPTON), polyester, polyamide (e.g, NYLON), or polypropylene.

The thickness of the shutter blades will depend on, among other things, the wavelength of the radiation and its intensity. Preferably, the shutter blades will be as thin as practical in order to minimize attenuation. Where the radiation is extreme ultraviolet EUV radiation having a wavelength of about 10 nm to 20 nm (EUV) the thickness of a metal shutter will typically range from 0.002 mm to 0.2 mm. The width of each shutter blade will typically range from 0.5 cm to 10 cm.

In preferred embodiments of the exposure shutter, the selection of (i) shutter blade thickness and (ii) number of shutter blades should minimize the attenuation of the intensity of the radiation that passes through the aperture of the

shutter frame in the open position. In addition, the exposure device should be in the fully closed position when the shutter blades have been rotated between 1 degree to 45 degrees and preferably between 5 degrees and 15 degrees along an axis that is parallel to the plane of the shutter frame aperture. This angle is determined by the width of the blades and the distance between them.

The exposure device can be readily scaled to accommodate energy beams having different size footprints. The major design limitations are the speed and shutter actuator torque requirements. The energy beam can comprise radiation having any wavelength, for example, of from 0.1 nm to 1 mm. The energy beams can be generated from any source including, for example, lasers, discharge sources, and synchrotrons. Appropriate lens and mirrors can be employed to generate substantially collimated beams for photolithography applications. It is expected that the exposure device can shutter energy beams that have cross sectional areas of from 5 cm^2 to 30,000 cm^2 or more. Typically for EUV photolithography applications, the radiation will have a footprint or cross sectional areas of from 5,000 cm^2 to 10,000 cm^2 . The exposure device is expected to operate in vacuum systems having a pressure that typically ranges from 0.1 torr to 10^{-8} torr, or less.

Figures 3A and 3B illustrate operations of shutter blades 26. As shown in Figure 3A, in the open position the shutter blades 26 are oriented parallel to the light path so that only a small amount of attenuation occurs. In the closed position, the frame is rotated just enough so that adjacent shutter blades overlap and the light is completely blocked as shown in Figure 3B. As is apparent, since the energy beams travel along the width of the shutter blades, the closer adjacent blades are positioned, the shorter will be the distance of rotation of the frame needed to fully shutter the energy beam. However, the amount attenuation of the

radiation when the shutter is in the open position also increases with the number of shutter blades used.

The rotary solenoid is used to move the shutter frame from the open to closed position in a short amount of time. The solenoid provides the required high torque output through a short distance. Typically, the larger the solenoid the faster the speed of rotation. Typically the drive means will move the frame from the open position to the closed position or from the closed position to the open position in a period of time ranging from 0.001 second to 0.1 second, or shorter. For EUV photolithography applications, this time period preferably ranges from 0.010 second to 0.001 second or shorter. Aside from the fully "open" and "closed" positions, it is understood that the solenoid can also be designed to move the shutter frame in and out of "intermediate" positions where the radiation is only partially intercepted. Another technique of increasing the speed of the shutter frame is to decrease the rotational moment of inertia about the solenoid shaft axis by minimizing the frame weight, with the proviso that it is also necessary to provide the frame with sufficient integrity and strength to withstand the force of the shutter blades that are stretched tightly between the sides of the shutter frame.

An exposure shutter similar to that shown in Figure 1 was fabricated and tested to shutter a visible light beam that had a diameter of approximately 4 inches (10.2 cm). The solenoid used was model Ultimag 5EM from Lucas Control Systems Products, Vandalia, OH. The rotary feedthrough was model SS-188-SLAA from Ferrofluidic Co. The visible light beam was generated by a helium/neon laser. The aluminum shutter frame had a 4 inch (10.2 cm) diameter and supported 22 aluminum shutter blades that were each 0.001 in. thick (0.0254 mm) and 1 in. (2.54 cm) wide. The shutter blades were spaced 0.15 in. (0.38 cm) apart. For this configuration, there was less than 1% transmittance loss (i.e., attenuation) when the shutter blades were in the open position. The activated

solenoid rotated the shutter frame 10 degrees in about 7 msec. to completely shutter the light beam. A feature of the exposure device employing the shutter blades is that the shutter blocked light nearly simultaneously as the shutters closed. This is in contrast to iris type shutters that block the light from the outside in and to the slide type of shutters that block the light from one side to another. Another feature of the shutter is that in the closed position it requires no power to be applied which limits heat generation, wear of the solenoid, and contamination.

Although only preferred embodiments of the invention are specifically disclosed and described above, it will be appreciated that many modifications and variations of the present invention are possible in light of the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.

WHAT IS CLAIMED IS:

1. An exposure device comprising:

a source of radiation that generates an energy beam;

a shutter that includes (i) a frame defining an aperture toward which the energy beam is directed and (ii) a plurality of blades that are secured to the frame; and

means for rotating the shutter to cause the plurality of blades to intercept or allow the energy beam to travel through the aperture.

2. The exposure device of claim 1 wherein each blade has a substantially planar surface and the plurality of blades are secured to the frame such that the planar surfaces of the plurality of blades are substantially parallel to each other.

3. The exposure device of claim 1 wherein the means for rotating the shutter comprise a solenoid that is encased in a vacuum compatible housing that entraps contaminants from the solenoid.

4. The exposure device of claim 1 wherein each blade has a width that ranges from about 0.5 cm to 10 cm.

5. The exposure device of claim 1 wherein the light beam is asubstantially collimated beam that has a cross sectional area of from about 5 cm^2 to 30,000 cm^2.

6. The exposure device of claim 1 wherein each blade is made from a metal that is selected from the group consisting of aluminum, steel, nickel, and titanium.

7. The exposure device of claim 1 wherein each blade is made from a plastic that is selected from the group consisting of vinyl, polytetrafluoroethylene, polyimide, polyester, polyamide, and polypropylene.

8. The exposure device of claim 1 wherein the source of radiation generates radiation having a wavelength of from about 0.1 nm to 1 mm.

9. The exposure device of claim 1 wherein the aperture has an area of between about 5 cm^2 to 30,000 cm^2.

10. The exposure device of claim 1 wherein the means for rotating the shutter comprises:

pivot means for pivoting the frame such that the plurality of blades rotates about an axis that is normal to the substantially planar surfaces of the plurality of blades; and

drive means for moving the frame in a controlled manner (i) from an open position that allows the energy beam to travel through the aperture to a closed position that intercepts the energy beam and (ii) from the closed position to the open position.

11. The exposure device of claim 10 wherein in the open position the substantially planar surface of each blade of the plurality of blades is parallel to the path of the energy beam when the frame is in the open position.

12. The exposure device of claim 10 wherein the drive means comprises means for moving the frame from the open position to the closed position or from the closed position to the open position within a time period that ranges from about 0.001 second to 0.1 second.

13. The exposure device of claim 10 wherein at least 90% of the intensity of the energy beam passes through the aperture when the frame is in the open position.

14. A method of patterning a substrate through controlled exposure of the substrate in a vacuum system which comprises the steps of:

generating radiation comprising an energy beam;

controlling the exposure with an exposure device that comprises a shutter that includes (i) a frame defining an aperture toward which the energy beam is directed and (ii) a plurality of blades that are secured to the frame; and

rotating the shutter to cause the plurality of blades to intercept or allow the energy beam to travel through the aperture.

15. The method of claim 14 wherein each blade has a substantially planar surface and the plurality of blades are secured to the frame such that the planar surfaces of the plurality of blades are substantially parallel to each other.

16. The method of claim 14 wherein the exposure device includes rotating the shutter that includes a solenoid that is encased in a vacuum compatible housing that entraps contaminants from the solenoid.

17. The method of claim 14 wherein each blade has a width that ranges from about 0.5 cm to 10 cm.

18. The method of claim 14 wherein the energy beam is a substantially collimated beam that has a cross sectional area of from about 5 cm^2 to 30,000 cm^2.

19. The method of claim 14 wherein each blade is made from a metal that is selected from the group consisting of aluminum, steel, nickel and titanium.

20. The method of claim 14 wherein each blade is made from a plastic that is selected from the group consisting of vinyl polytetrafluoroethylene, polyimide, polyester, polyamide and polypropylene.

21. The method of claim 14 wherein the source of radiation generates radiation having a wavelength of from about 0.1 nm to 1 mm.

22. The method of claim 14 wherein the aperture has an area of between about 5 cm^2 to 30,000 cm^2.

23. The method of claim 14 wherein the exposure device includes means for rotating the shutter that comprises:

pivot means for pivoting the frame such that the plurality of blades rotates about an axis that is normal to the substantially planar surfaces of the plurality of blades; and

drive means to move the frame in a controlled manner (i) from an open position that allows the energy beam to travel through the aperture and a closed position that intercepts the energy beam and (ii) from the closed position to the open position.

24. The method of claim 23 wherein the substantially planar surface of each blade of the plurality of blades is parallel to the path of the energy beam when the frame is in the open position.

25. The method of claim 23 wherein the drive means comprises means for moving the frame from the open position to the closed position or from the closed position to the open position in less than from about 0.001 second to 0.1 second.

26. The method of claim 23 wherein at least 90% of the intensity of the energy beam passes through the aperture when the frame is in the closed position.

ABSTRACT

An in-vacuum radiation exposure shutter device can be employed to regulate a large footprint light beam. The shutter device includes (a) a source of radiation that generates an energy beam; (2) a shutter that includes (i) a frame defining an aperture toward which the energy beam is directed and (ii) a plurality of blades that are secured to the frame; and (3) device that rotates the shutter to cause the plurality of blades to intercept or allow the energy beam to travel through the aperture. Each blade can have a substantially planar surface and the plurality of blades are secured to the frame such that the planar surfaces of the plurality of blades are substantially parallel to each other. The shutter device is particularly suited for operation in a vacuum environment and can achieve shuttering speeds from about 0.1 second to 0.001 second or faster.

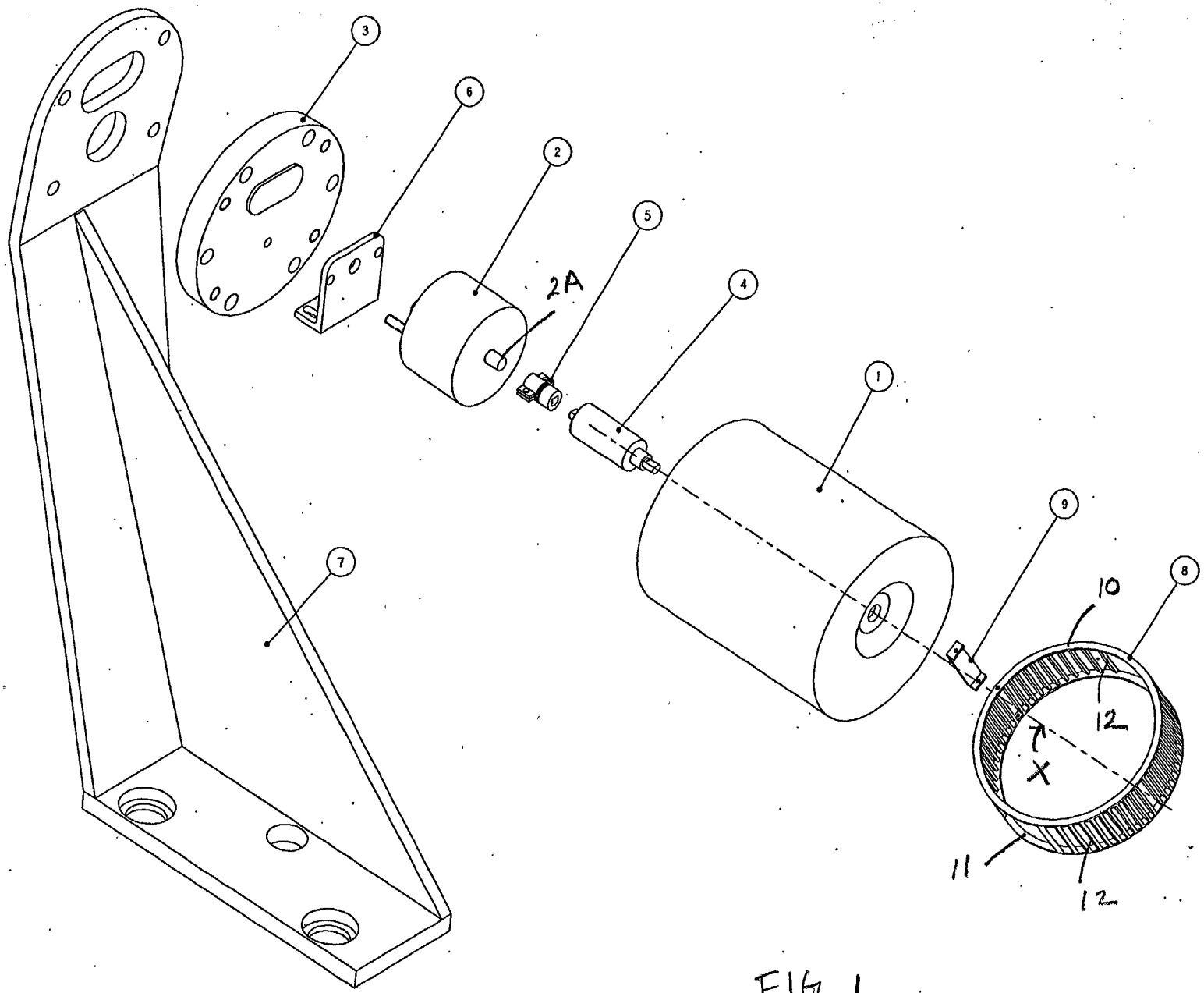

FIG 1

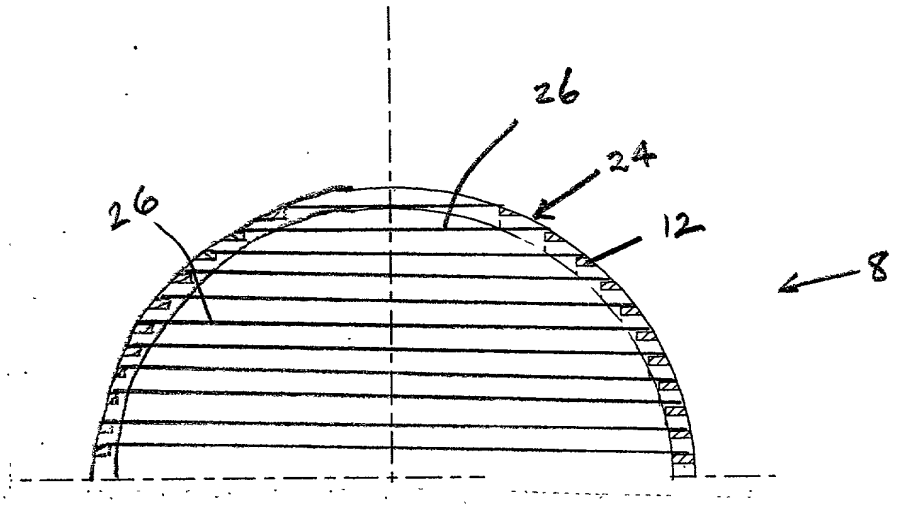

FIG 2

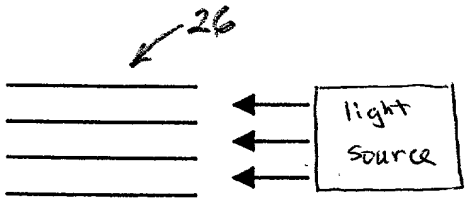

FIG 3A

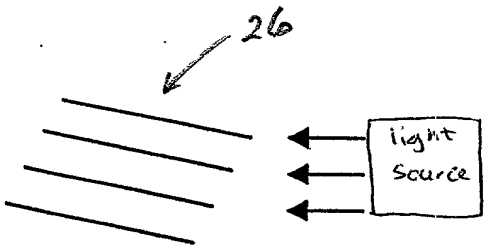

FIG 3B

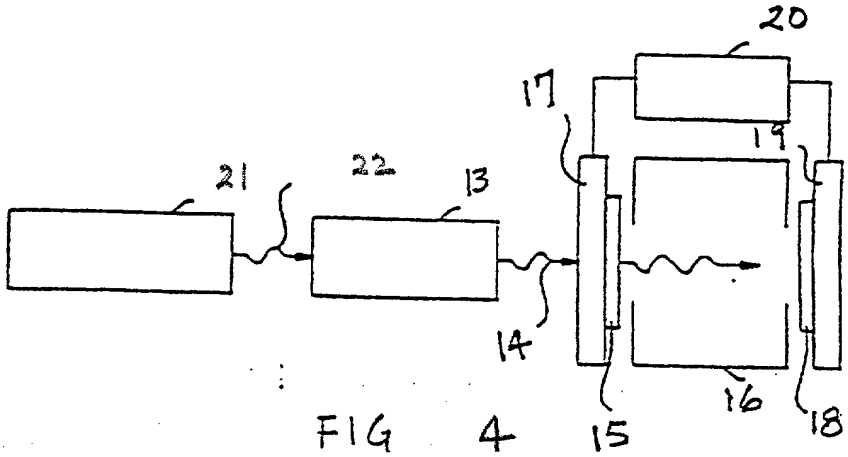

FIG 4

COMBINED DECLARATION AND POWER OF ATTORNEY FOR UTILITY PATENT APPLICATION	Attorney's Docket No. 023890-031 (SD-8267)

As a below-named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below next to my name;
I BELIEVE I AM THE ORIGINAL, FIRST AND SOLE INVENTOR (if only one name is listed below) OR AN ORIGINAL, FIRST AND JOINT INVENTOR (if more than one name is listed below) OF THE SUBJECT MATTER WHICH IS CLAIMED AND FOR WHICH A PATENT IS SOUGHT ON THE INVENTION ENTITLED:

IN-VACUUM EXPOSURE SHUTTER

the specification of which

(check one) ☒ is attached hereto;

☐ was filed on _____ as

Application No. _____

and was amended on _____ ; (if applicable)

I HAVE REVIEWED AND UNDERSTAND THE CONTENTS OF THE ABOVE-IDENTIFIED SPECIFICATION, INCLUDING THE CLAIMS, AS AMENDED BY ANY AMENDMENT REFERRED TO ABOVE;

I ACKNOWLEDGE THE DUTY TO DISCLOSE TO THE OFFICE ALL INFORMATION KNOWN TO ME TO BE MATERIAL TO PATENTABILITY AS DEFINED IN TITLE 37, CODE OF FEDERAL REGULATIONS, Sec. 1.56 (as amended effective March 16, 1992);

I do not know and do not believe the said invention was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to said application; that said invention was not in public use or on sale in the United States of America more than one year prior to said application; that said invention has not been patented or made the subject of an inventor's certificate issued before the date of said application in any country foreign to the United States of America on any application filed by me or my legal representatives or assigns more than twelve months prior to said application;

I hereby claim foreign priority benefits under Title 35, United States Code Sec. 119 and/or Sec. 365 of any foreign application(s) for patent or inventor's certificate as indicated below and have also identified below any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application(s) on which priority is claimed:

COMBINED DECLARATION AND POWER OF ATTORNEY	Attorney's Docket No. 02389-031 (SD-8267)

COUNTRY/INTERNATIONAL	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED
			YES_ NO_
			YES_ NO_

I hereby appoint the following attorneys and agent(s) to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and to transact all business in connection with international applications directed to said invention:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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COMBINED DECLARATION AND POWER OF ATTORNEY	Attorney's Docket No. 02389-031 (SD-8267)

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FULL NAME OF FOURTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF FIFTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF SIXTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF SEVENTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF EIGHTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF NINTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		
FULL NAME OF TENTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE		CITIZENSHIP
POST OFFICE ADDRESS		